

Acronym: BCAT-5-Aspheres

Payload Title: Binary Colloidal Alloy Test - 5: Aspheres

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Sponsoring Agencies: National Aeronautics and Space Administration (NASA)

Increment(s) Assigned: 19, 20

Mission Assigned: N/A

Brief Research Summary (PAO): The Binary Colloidal Alloy Test - 5: Aspheres (BCAT-5-Aspheres) experiment photographs initially randomized colloidal samples (tiny nanoscale spheres suspended in liquid) in microgravity to determine their resulting structure over time. BCAT-5-Aspheres will study the properties of concentrated systems of small particles when they are identical, but not spherical in microgravity..

Research Summary:

- Binary Colloidal Alloy Test - 5: Aspheres (BCAT-5-Aspheres) is one of four investigations in the BCAT-5 suite of experiments. BCAT-5-Aspheres utilizes sample 9 in the BCAT-5 hardware.
- BCAT-5-Aspheres will explore the fundamental problems of how densely differently shaped particles pack, e.g. do ellipsoids or tetrahedra pack denser randomly or in a crystalline array? This addresses an age old problem of the geometry dependence of glasses and crystals.
- BCAT-5-Aspheres scientists expect that work with non-spherical particles will lead to the discovery of new liquid crystalline phases and in general to new condensed phases of matter. Traditional questions about the relative packing fractions, which crystallization phase is manifested, and the passing from one phase to the other, may be studied in these systems without the perturbing effects of sedimentation and gravitational jamming.

Detailed Research Description: The Binary Colloidal Alloy Test - 5 (BCAT-5) hardware supports four investigations. Samples 1 - 5, the Binary Colloidal Alloy Test - 5: Phase Separation (BCAT-PhaseSep) will

study collapse (phase separation rates that impact product shelf-life). In microgravity the physics of collapse is not masked by being reduced to a simple top and bottom phase as it is on Earth. Samples 6 - 8, Binary Colloidal Alloy Test - 5: Compete (BCAT-5-Compete) will study the competition between phase separation and crystallization, which is important in the manufacture of plastics and other materials. Sample 9, Binary Colloidal Alloy Test - 5: Aspheres (BCAT-5-Aspheres) will study the properties of concentrated systems of small particles when they are identical, but not spherical; this could impact how light bends with angle and crystal orientation, strength, temperature transfer as a function of direction, *etc.* Sample 10, Binary Colloidal Alloy Test - 5: Three-Dimensional Melt (BCAT-5-3D-Melt) will look at the mechanisms of melting using 3 dimensional temperature sensitive colloidal crystals.

The BCAT-5-Aspheres sample will consist of anisotropic (directionally dependent property) hard particles which have different thermodynamics and kinetics than that found for spherically-symmetric particles. The condensed phases for these particles are much richer, and include orientationally-ordered states which lack periodicity (liquid crystal-like phases), and crystalline phases which lack orientational order (rotator phases). A good deal of the behavior of these systems is governed by their entropy (a measure of the energy that is not available for work during a thermodynamic process) which in turn is related to the ordered and random packing densities. In granular systems we have found that ellipsoids, the simplest non spherical shape, have random packing that is almost as high as its periodic packing. The driving force toward ordering is thus very small and the system may present a unique way to study glassy dynamics in a monodisperse suspension. We therefore plan experiments on colloidal suspensions of ellipsoidal particles of different aspect ratio.

Project Type: Payload

Images and Captions:



Astronaut Dan Tani photographing the BCAT-3 Sample Module using his own design for a ceiling mount in Node 2 of the International Space Station. Great high contrast pictures of difficult-to-capture images resulted from using this setup (February 2008).

Operations Location: ISS Inflight

Brief Research Operations:

- The BCAT-5 hardware consists of ten different individual sample cells comprising 4 investigations, BCAT-5-Aspheres utilizes sample cell 9.
- For the BCAT-5-Asphere sample crewmembers will homogenize the sample and will look for crystals at various lighting angles. The crystals will be manually photographed and these photos downlinked allowing immediate feedback to the crewmembers.
- If crystals are found, the camera and lighting will be positioned at an angle that best captures this and the sample will be rehomogenized and a new round of photographs will be taken using the EarthKAM software. This will capture the kinetics of crystal formation.
- After photography, the BCAT-5 hardware is stowed and left undisturbed to allow for the continued growth of the colloidal structure for up to 6 months.

Operational Requirements: The BCAT-5 experiment consists of ten small samples of colloidal particles. The ten BCAT-5 samples are contained within a small case the size of a school textbook. The experiment requires a crewmember to set up on the Maintenance Work Area (MWA) or on a handrail/seat track configuration, ISS Laptop and utilize EarthKAM software to take digital photographs of the samples at close range using the onboard Kodak DCS760 camera. Camera Control Files for running the EarthKAM software can be uploaded from Earth to control the photography intervals (how many photographs per hour) and spans (run for how many days) once it is running. Some samples, which may form crystals, require manual photographs (at least initially) be taken by the crewmember. The pictures are downlinked to investigators on the ground for analysis.

Operational Protocols: A crewmember sets up the video camera and BCAT-5 hardware (Slow Growth Sample Module, DCS760 Camera, pen-light source, flash and SSC Laptop with EarthKAM software) in the Maintenance Work Area (MWA) to document the BCAT-5 operations as performed on-board the ISS. The crewmember homogenizes (mixes) the sample(s) and takes the first photographs manually. This helps them optimize the setup and shows that the samples were initially fully homogenized when publishing results later. The EarthKAM software automates the rest of the photography session over a few days to 3-week period. The crewmember performs a daily status check once a day (when time is available) to assure proper alignment and focus. At the completion of the run, the crewmember tears down and stows all hardware.

Category: Physical Sciences in Microgravity.

Subcategory: Materials Sciences

Space Applications: BCAT-5-Aspheres will ultimately impact our understanding of the strength and thermal conductivity of materials by providing insight into the effects of size variation in dense suspensions of particles.

Earth Applications: Generally, colloidal nucleation experiments seek an understanding of the most fundamental liquid/solid transition. Particle shape impacts the rise of order out of disorder. Though direct applications of that understanding do not yet drive the research, growth of ordered colloidal phases has attracted interest in a number of areas, e.g. ceramics, composites, optical filters and photonic bandgap materials. The use of asymmetric particles may produce directionally dependent crystal properties, and the use of particles whose size depends upon temperature may afford temperature tunable crystals.

Manifest Status: Reserve

Supporting Organization(s): Exploration Systems Mission Directorate (ESMD)

Previous Missions: The predecessors to BCAT-5, BCAT-3 and BCAT-4 are in operation on the ISS.

Results: N/A

Related Publications:

Man WN, Donev A, Stillinger FH, Sullivan MT, Russel WB, Heeger D, Inati S, Torquato S, Chaikin PM. Experiments on Random Packings of Ellipsoids. Physical Review Letters. 2005; 94, 198001.

Donev A, Stillinger FH, Chaikin PM, Torquato S. Unusually Dense Crystal Packings of Ellipsoids. Physical Review Letters. 2004; 92, 255506-1.

Donev A, Cisse I, Sachs D, Variano EA, Stillinger FH, Connelly R, Torquato S, Chaikin PM. Improving the Density of Jammed Disordered Packings Using Ellipsoids. Science. 2004 ;303, 990-993.

Web Sites:

Binary Colloidal Alloy Test - 3 (BCAT-3)

http://exploration.grc.nasa.gov/life/bcat3_iss.html,

Related Payload(s): [BCAT Investigations](#), [EXPPCS](#)

Last Update: 10/102008.